PATENT SPECIFICATION

764,993

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COMPLETE SPECIFICATION

Improvements in Refrigerated Clothing

I, VIRGIL STARK, a Citizen of the United States of America, of 405, Lexington Avenue, Chrysler Bldg, New York 17, New York, United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to refrigerated clothing and means for creating bodily comfort.

Human beings, as is well known, continuously produce heat by metabolism, both when active and at rest, which heat must be dissipated as produced in order to avoid an increase in the bodily temperature to the point of sensible discomfort.

The human body is producing heat either while resting (basal metabolism) measured in met (metabolic rate of 50 calories per sqm of body surface per hour) or when in activity (metabolic cost), and the heat thus generated is dissipated in the environment by radiation, conduction, convection and evaporation to maintain thermal equilibrium. This equilibrium is only attainable if the environment is capable of accepting such heat as fast as it is generated without rise in body temperature above physiological limits.

Direct transfer of heat through radiation and convection from the body becomes impossible if the temperatures of the environment are higher than the allowable upper limit of the mean surface temperature of the body. The indirect heat dissipation through evaporation can continue to dissipate heat even at higher ambient temperature than the skin temperature.

The heat dissipation through evaporation and perspiration is, however, limited by the water acceptance capacity of the environment. No such heat transfer is possible if the vapor pressure of the environment rises above that obtainable on a complete wet skin at allowable upper limit of skin temperature.

The normal transfer of the heat generated by the human body is therefore limited by the ambient temperature and its vapor pressure. The feeling of discomfort up to heat exhaustion and final death may be the consequence of such limitations if no provision for alleviating discomfort is made.

The object of this invention is to obtain by a system including proper refrigerated clothing around the human body an intermediate environment of comfort even if the ambient temperature and/or vapor pressure or sun radiation would otherwise make the human body feel uncomfortable or result in exhaustion or death.

The invention aims to promote sustained bodily comfort by maintaining thermal equilibrium in the body within the range corresponding to a mean skin temperature of 32°C to 33.5°C.

The invention consists of a properly designed clothing of suitable material provided with a refrigeration system consisting of a refrigerant such as dry ice carried in a refillable container, combined with a heat transfer element and a system of partition and distribution of the flow of ambient air cooled by the refrigeration system which will carry away the heat generated by the human body, and the evaporated water from sweat.

The system will consist of the following elements:

1. A clothing in form of a cloak or a suit made from insulating material which may include in the fabric powdered metal or other reflecting elements of the sun radiation.

2. A collar in such clothing in which a metallic refillable container is introduced.

3. One or several containers provided with fins or other provisions for increasing their heat transfer surface, such container

[Price 3s. 0d.]

or containers being partially filled with carbon dioxide in solid form.

4. Partition allowing the contact of ambient air with the surface of the container, the cooling of the air and passage of the cooled air in the space between the body and the outside insulated clothing.

5. A system of distribution of the cooled air and of the CO_2 vapor from the container.

6. A system of regulating the release of CO_2 vapor from the container and regulating the refrigeration effect.

7. A system regulating the volume of air in circulation by variation of the surface of passage made through a sliding insulating cover above the container and by variation of transfer surface between the metallic container and the ambient air on the one hand, and between the solid dry ice or vapor dry ice and the metallic container on the other hand, by using a device interposed between the solid dry ice and the container located at its inside.

The following items may be added to the system as auxiliary devices which are not indispensable to its operation but add to its efficiency:

8. An auxiliary heat transfer tube or coil carrying the CO_2 vapor released from the container forming an additional cooling surface for ambient air.

9. A system of ejectors in which the CO_2 vapor is used for suction of the air to be cooled, increasing the volume passing through the cooler.

10. A system including a pressure regulator and nozzle which reduces the pressure of the CO_2 vapor with further cooling of such vapor.

This system will operate as follows:

The ambient air will be cooled when in contact with the cold metallic surface of the container partially filled with solid CO_2 (−61°C at 1 atm.). The cooler air is heavier than the warmer ambient air and will tend to flow to the ground. The latent heat of sublimation or latent heat of vaporization of the CO_2 will supply the main refrigeration of the air flow.

The CO_2 vapor produced may be released from the container through a regulating valve and eventually a pressure regulator instead of directly in the air flow and the sensible heat of the cold CO_2 vapor will supply additional refrigeration (through a cooling coil which will further cool the air and heat the CO_2 vapor and increase its volume). Although not indispensable to the system, the CO_2 vapor released may pass through one or more nozzles surrounded by the incoming cooled air passing through an ejector and will have a suction effect which will increase the volume of air passing through the cooler. The pressure drop through the nozzles will reduce the temperature of the CO_2 vapor which has been heated before in the air cooling coil.

The metallic container partially filled with CO_2 may be provided with a relief valve which can be set for a certain maximum pressure and corresponding temperature. If the production of CO_2 vapor in the container is higher than the volume of the vapor allowed to be released through the regulating valve, the pressure in the container will increase up to the maximum pressure, at which the relief valve is set. The temperature of the container which is also the cooling element of the air can therefore be regulated by setting the relief valve on the one hand, and the flow regulating shutoff valve on the other hand.

The cooled air and CO_2 vapor flow will absorb the heat generated by the human body and dissipated through radiation and convection, and the temperature of the air will gradually increase as it flows downward.

In short, my invention comprises properly designed clothing of suitable material and a refrigeration means utilising solid carbon dioxide (dry ice) or other refrigerant adequate for obtaining by refrigeration and gravity difference a flow of cooled ambient air in the immediate environment of the body, together with control devices for regulating the temperature and flow of the air and refrigerant gas mixture in such environment.

My system preferably is put into effect by means of an encompassing garment such as a cloak or a suit made out of insulating or radiation reflecting material which may include metallic particles; a supporting means for a container for solid or liquid refrigerant, which may take the form of a collar in said garment; a heat absorbing container for the refrigerant, provided with fins, partitions or other heat transfer means for cooling and directing the flow of air and distributing it within the garment, and means to control the volume of air in circulation and its heat exchange relation with the container, which may include a movable cover.

I prefer to use solid carbon dioxide as the refrigerant material, as this volatilizes at −61°C and the vapor is heavier than air at the same temperature, forming therewith a cold mixture which tends to flow to the ground. The latent heat of sublimation of solid CO_2 is 136 cal. per kg, which, added to its sensible heat of CO_2 cold vapor of approximately 30 cal/kg makes available about 166 cal. per kg. for refrigerating the ambient air in the intermediate environment of my system. The CO_2 vapor released in the environment and thereafter in the ambient air has the advantage of being an

inert gas, therefore not inflammable and also a gas which is not toxic and harmless. The introduction of CO_2 vapor in the air flow will also tend to reduce the vapor pressure of the mixture.

A preferred design of garment and air cooling and regulating means operating according to my system are shown in the accompanying drawings, wherein:—

Figs. 1 and 2 are, respectively, a front and a side elevation, partially in section, of a manikin wearing a refrigerated clothing according to this invention;

Fig. 3 is a longitudinal sectional elevation, drawn to a larger scale, of the refrigerating apparatus;

Fig. 4 is a transverse sectional elevation, on line IV-IV of Fig. 3; and

Fig. 5 is a sectional elevation of a modified embodiment of the refrigerating apparatus.

In the embodiment of this invention shown on Figs. 1-4 of the drawings, a loosely fitting garment 11 of conventional style is worn by a manikin 12, the loose fit of the garment below the shoulders providing an encircling space 13 around the body of the wearer. On the inner face of said garment are secured upstanding ribs 35 causing said garment to be spaced away all around from the body and facilitating the circulation of the downwards moving airflow. A refrigerating device 14 is supported on the shoulder of the user or manikin 12, by means of an insulating pad 27, for providing the desired environment within space 13.

The garment 11 is made of insulating material, the outside part preferably being adapted to reflect the sunshine radiation by provision of proper means, such as metal powder embedded into the cloth, or adhering to its surface or mixed with plastic and coated on cloth, or metals forming continual layers such as aluminium foil or lame, or metal strip wrapped around the yarns. However, the inside of the cloth used for making the garment may be different from the outside in order to increase absorption of the heat diffused by radiation from the body.

An insulating cap or headcover 16 may be worn on the wearer's head, and be provided with a small container 14*a* for a refrigerant to cool the air, and an open spacing between the head and the headcover to allow the cooled air to flow downwards around the head and continuing along the neck, to which it may be conducted by a fabric extension of the cap or headcover.

A hood may be secured to the garment about the collar for additional protection from the sun radiation while receiving the flow of refrigerated air from the head, and pants or a skirt 9 may be secured to the lower part of the garment for extending the intermediate environment to afford additional protection and comfort. The refrigeration means 14 comprises a cylindrical container 22 provided with a number of fins 26 on its exterior which are welded or otherwise secured thereon.

The container is supported by a shoulder pad 27 to which it is secured. Between the shoulder pad and the underside of the container, beneath the lower edges of the fins 26, a trough 18 is provided to collect moisture from the air which may condense on the fins. A drip pipe 15 at one end of the trough leads to a sponge, not shown, located in an aperture in the garment 11 to receive this moisture and protect the wearer's clothing.

One end of the container 22 is closed and the opposite end is covered by a removable cap 22*a* which is secured to one end of a horizontal cylinder 36, the other end of which is open to receive a charge of solid carbon dioxide, and which fits loosely within the cylinder 22. The upper half of this cylinder 36 is provided with orifices 37, and similar orifices (not shown) are provided in the upper part of the outer cylinder 22 said latter orifices being closed by the cylinder 36 or registering with the orifices 37 when the cylinder 36 is rotated so as to change the heat transfer factors. A sheet of insulation 34 may lie within and be secured to the cylinder 36 and normally supports the solid carbon dioxide charge to protect it from direct contact with the metal of the container.

A sliding flexible cover 30 running lengthwise on tracks extending along the top edges of the refrigerating device 14, and one end of which is rolled upon the shaft 39, may be manually adjusted lengthwise to uncover a greater or lesser area of the top entrance 17 into the refrigerating device 14 and expose a larger or smaller number of the fins 26 to the flow of air therethrough, thereby affording a measure of control over the refrigeration process.

The air flow created by gravity differences between the heavier air cooled by the cold fins and containers filled with solid dry ice and the ambient warm air will be conducted into the compartments of the intermediate environments between the body and the insulating garment and the air and CO_2 vapor flowing downwards in such interspace will be gradually heated by the heat generated by the human body.

The regulation of the air flow and setting of the temperature in such intermediate environment will be obtained either by varying the surface of entrance of the warm air by using the sliding cover 30 over the top entrance 17 or by rotating the cylinder 36,

by means of the end 22*a*, with the movable support 34 of the solid dry ice thus varying the direct contact and transfer surface of the ice with the finned container.

The refrigerating apparatus shown in Fig. 5 comprises additional devices not indispensable but increasing the efficiency of the system. Here the finned container 22*b* is pressure resistant and is provided with a safety relief valve 28 allowing a further regulation of the temperature by permitting an adjustable pressure of CO_2 vapor to be established in the container. The CO_2 vapor is conducted through a valve 24 in a tube 21, through a removable connection 23, and then through a pressure regulator 25 to a coil 33 and a nozzle 20. The CO_2 surplus vapor released through the safety valve 28 passes into a cover 29 and then through passages 32. An ejector passage 19 provided in the casing of the apparatus cooperates with nozzle 20 for increasing, by the suction effect thus obtained, the volume of air drawn through the device when in operation. A collector, and distributing pipes 31, may be provided for circulating the mixture of cooled air and CO_2 vapor as desired. Moisture from condensation which may collect on the fins 26 will drip on to transverse rails 18*a* and thereby be conveyed to a wall of the casing.

This invention will not only create an intermediate environment temperature lower than the ambient one, thus changing the proportion of heat dissipation by evaporation, convection and radiation, but also will activate the heat dissipation by convection (forced convection) and evaporation by increasing the velocity of the surrounding intermediate air flow.

The convection heat transfer will more than double if the air velocity increases from 10 feet/min. to 50 feet/min.

Experience shows that the effect of air movement increases the cooling power of air and results in a more pleasant feeling at higher temperatures. The evaporative dissipation of heat is increased with higher velocity of the air and will vary as the square root of the air velocity. The heat absorbed by the air and CO_2 flow in the intermediate environment will correspond only to the heat dissipated by the body in form of radiation and convection. Such heat dissipation by radiation and convection is nil when the ambient temperature is equal to the mean skin temperature (when all heat dissipation is made only through perspiration and evaporation) and increases with the temperature differential. Therefore, the heating of the air and CO_2 flow in the intermediate environment space will depend on the temperature selected for such flow for comfort conditions. The temperature increase of the flow and the outlet temperature from the intermediate space will also depend on the volume of air passed through, the initial temperature (atmospheric temperature), the amount of refrigeration and also the velocity of such flow. As illustrated above, both the air volume and refrigeration can be regulated so that the heating of the air flow and its temperature can be set as desired considering the conditions selected and the atmospheric conditions. All of the above factors will determine the consumption of dry ice and therefore the charge of dry ice necessary and its duration.

The introduction of CO_2 in the intermediate environment will change the heat radiation conditions as CO_2 has higher emissivity and radiation absorption than air and will thus increase the carrying away of heat from the body by radiation dissipation.

Other refrigerants than dry ice can be used with the above system, such as liquid nitrogen, liquid oxygen, liquid air, ice, hydrogen peroxide etc. with proper adaptation and modification thereof.

This invention can also be applied to cover and cool only specific parts of the human body such as arms, legs, etc. increasing the heat dissipation in such parts and obtaining a feeling of pleasantness for the whole body.

The invention can be applied also for creation of intermediate comfort environment for a larger covering or surrounding of the human body other than clothing, such as blankets etc. with proper adaptations.

From the foregoing it is evident that the invention proposes to create an intermediate environment between the human body and the outside ambient which will have the following effects:

1. Decrease the ambient temperature to an operating temperature of comfort.
2. Change the proportions of heat dissipation by evaporation on the one hand and radiation and convection on the other hand by change of environmental conditions to differ from ambient conditions.
3. Increase the transfer through convection and evaporation by increasing the velocity of the air flow.
4. Increase the radiation heat transfer direct from the body by proper clothing.
5. Increase the reflection of the sunlight radiation.
6. Regulate the system to the desired conditions.

The invention would have a large use not only in desert and tropical climates, but also in industries where work is done in hot environments, including furnaces, rolling mills, glass works, boiler rooms, cement works, and in the armed forces and in naval and other vessels where high tem-

peratures may prevail.

In the claims the word "garment" is used to connote not only clothing but also outer coverings or surroundings encompassing the human body or parts thereof such as hats, helmets, caps and similar, also blankets, ponchos and other means serving as loose cloaks for protecting the wearer.

What I claim is:—

1. A portable device for creating a protective intermediate environment between parts of the human body and the ambient atmosphere by means of an encompassing garment, and if needs be of a headcover, said garment being made of insulating substance and having inner ribs providing between said garment and the adjacent parts of the human body passages for circulation of air and possibly of a vapour, characterised in that at least a portion of the opening in said garment provided for the passage of the head of the wearer is surrounded with a collar associated with a cooling apparatus arranged and adapted to be supported on the shoulders of the user and providing an inlet for causing thermal circulation of the atmosphere within said passages, said cooling apparatus essentially comprising a finned container charged with a replaceable vaporizable refrigerant, and means for controlling the vaporization rate of said refrigerant and the flow of air through said cooling apparatus which is connected through its bottom portion with said passages.

2. A portable device according to claim 1, in which the ribs of the garment, forming passages for circulation of air, are vertically disposed and extend from top to bottom of said garment.

3. A portable device according to claim 1, in which said cooling apparatus forms atmospheric humidity condensing means arranged for trapping moisture in the entering air, and is associated with a slightly sloping trough disposed under said condensing means and provided with a drip pipe for leading the condensed moisture outward.

4. A portable device according to claim 1, in which the finned container is provided with a regulating device consisting of an insulating support for the refrigerant which is removably and adjustably positioned inside said container with provisions to move one with respect to the other for controlling the amount of exposed surface of heat transfer of the refrigerant.

5. A portable device according to claim 1, in which said container is a finned closed metallic container provided with a control valve to regulate the release of the refrigerant vapour so as to obtain more or less heat absorption from the latent heat of sublimation of the refrigerant, and with a safety relief valve set at a desired pressure and arranged for admixing the refrigerant vapour into the air passing through said apparatus in case of opening of said safety relief valve.

6. A portable device according to claim 5, in which a nozzle for refrigerant vapour is connected to said closed metallic container with a co-operating pressure regulator to increase the cooling effect by pressure drop of said vapour, said nozzle being combined with an ejector for suction of ambient air through said cooling apparatus.

7. A portable device according to claim 6, in which the connection between said nozzle and said closed metallic container is an additional heat transfer element formed of a coil through which passes the released refrigerant vapour at low temperature before being further cooled by its expansion in the nozzle.

8. A portable device according to claim 1, in which the means for controlling the flow of air through said cooling apparatus consist in a slidable cover which is adjustable with respect to an air passage affecting flow past the finned container.

9. A portable device according to claim 1, in which a headcover providing space surrounding the head of the wearer encloses at its upper portion a refrigerant container partially provided with fins, inlet openings for ambient air being arranged at the top portion of said headcover, means for directing the air passing through said openings between the fins of said container for cooling said air, and controlling means of the air flow rate constituted by movable members capable of adjusting the used area of said inlet openings.

10. A portable device according to any one of the previous claims, wherein the refrigerant is carbon dioxide.

11. A portable device according to claim 10, wherein the refrigerant is solid carbon dioxide.

12. A portable device according to any one of the previous claims, constructed and arranged substantially as described herein and illustrated in the accompanying drawings.

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Chartered Patent Agents.

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Fig.1

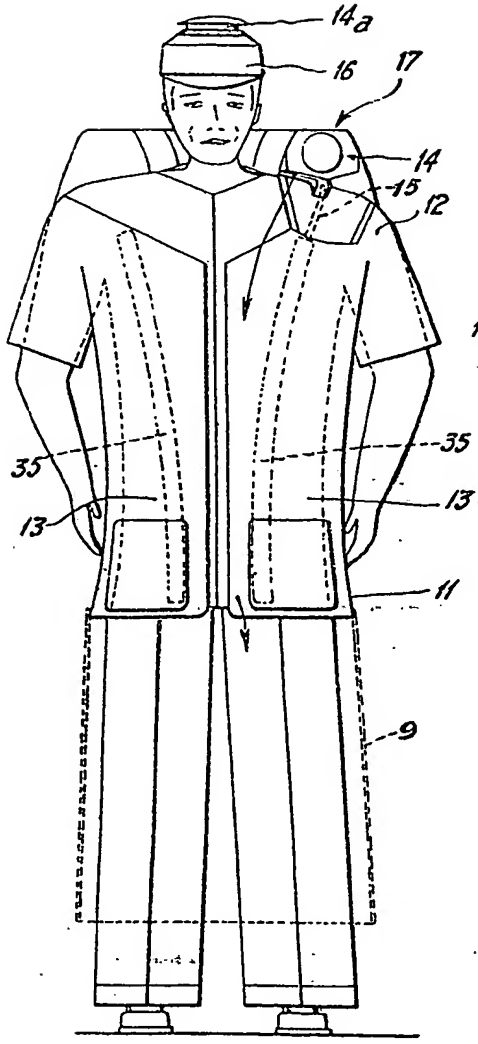
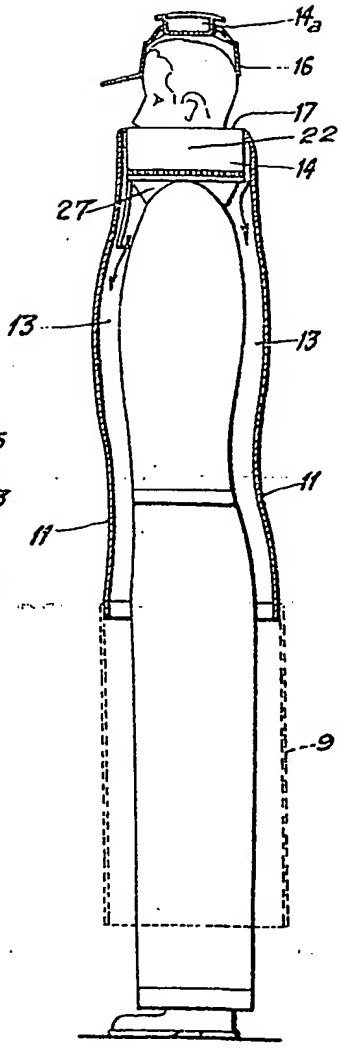


Fig.2



764,993 COMPLETE SPECIFICATION

2 SHEETS

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SHEETS 1 & 2

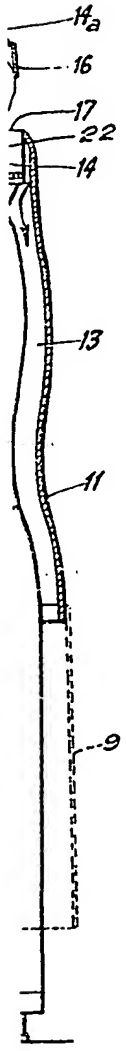


Fig. 3

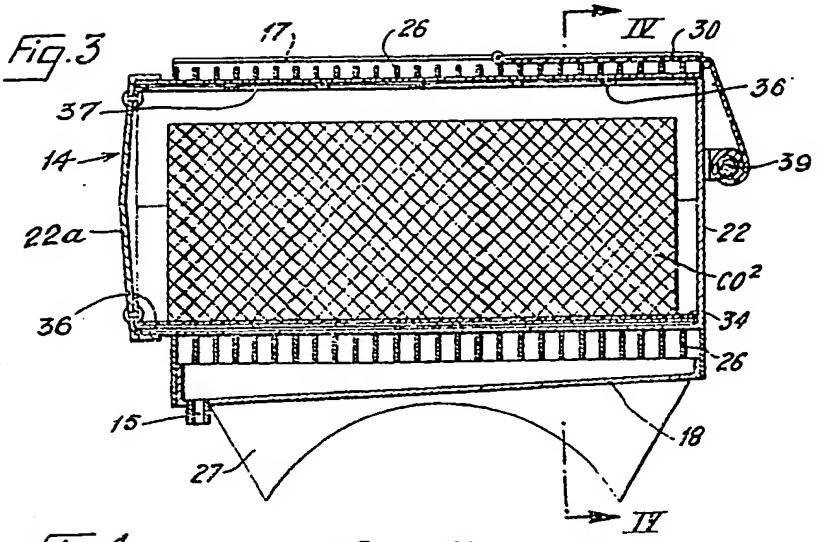


Fig. 4

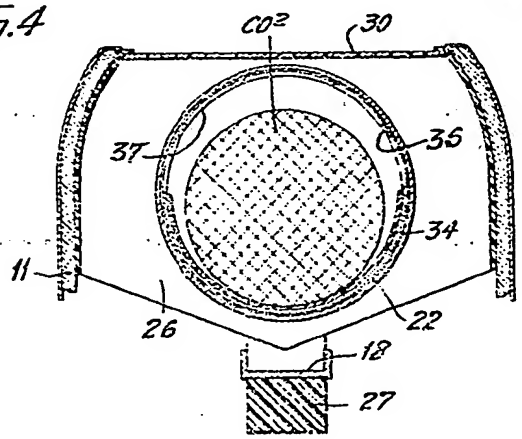
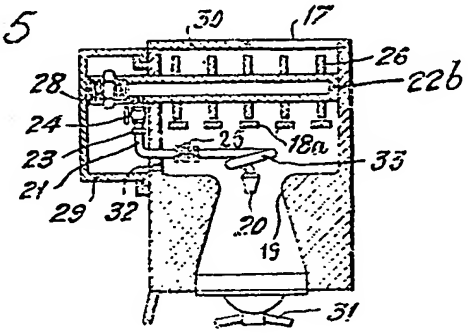


Fig. 5



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SHEETS 1 & 2

Fig.1

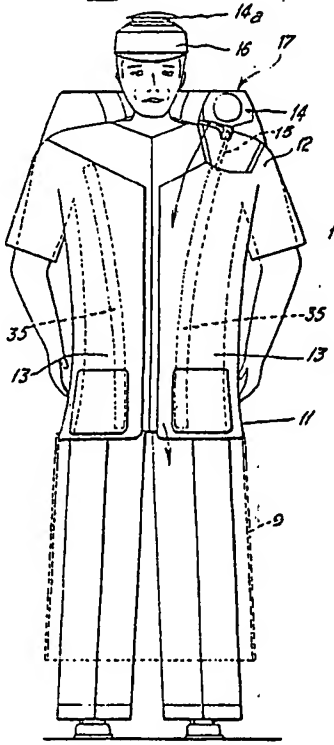

Fig.2

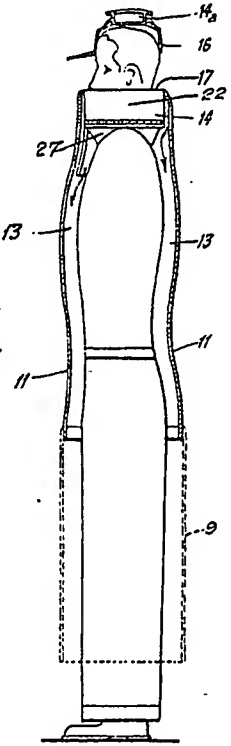

Fig.3

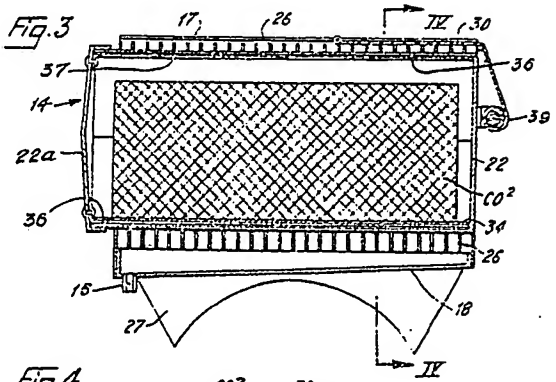

Fig.4

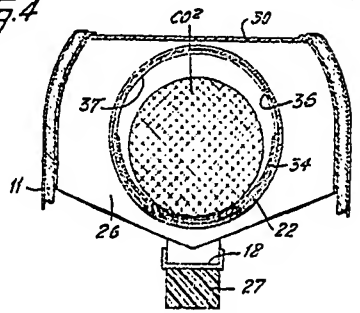

Fig.5